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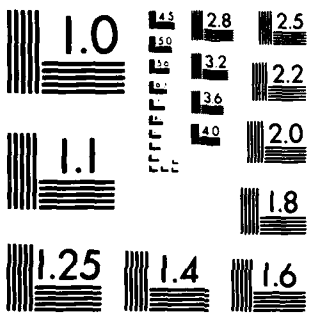

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ON AIRCRAFT ANTENNAS AND BASIC SCATTERING STUDIES

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This report summaries the work accomplished in each of two areas. The on-aircraft studies involved the GTD analysis of a strip scatterer in the near field of an antenna. In addition, a method for determining the aperture distribution of a linear array through near field measurements has been developed. The basic scattering studies portion attempts to provide an understanding of ray optical solutions and UTD in particular for the analysis of scattering from basic shapes. Specific examples of scattering from plate models, composite cone frustrums and the near zone effects of a basic aircraft model are presented.

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INTRODUCTION

This report summarizes the work done on Contract No. N62269-80-C-0384. The overall program was divided into two areas. These are:

1. On-aircraft studies, and
2. Scattering studies.

This report gives a brief summary of the research in each area. For more details the reader should see the following reports:

1. On-aircraft studies.

   a. "GTD Analysis of a Strip Scatterer in the Near Field of an Antenna", (Technical Report 713303-1).

   b. "The Determination of the Aperture Distribution of a Linear Array through Near Field Measurements", (Technical Report 713303-2).

2. Scattering Studies.

   a. "High Frequency Basic Scattering Study", (Technical Report 713303-3).

The following sections summarize the research accomplished in each of these two areas.

ON-AIRCRAFT STUDIES

In this research a synthesis technique was applied to determine array excitations from measured near field data with promising success. The task here was to find the set of currents which existed on an array using measured near field data. This was accomplished, in part at least, through relating discrete point currents of the array to a measured, radiated near field in an overconstrained matrix equation and solving for the excitations.

Four near field measurements were made on the array with 169 magnitude and phase data points acquired from each measurement session. The measurements were made by moving a probe along a line parallel to and in the H-plane of the array. Each measurement set was taken with the line of measurement displaced a different distance from the array. The measurement spanned approximately 8λ to each side of the center of the array and the component of the electric field aligned with the array dipoles was measured with a balanced dipole probe. The measurement design was such that the probe was always in the far field of any individual array element. Also the measurement axis was perpendicular to the dipoles so that the element factor of the array elements and the probe was of the same value at every measurement point.

The synthesis technique which uses the near field measurement of both magnitude and phase shows considerable promise as a relatively inexpensive and reliable method to determine a set of currents of an array which have corresponding radiated fields that match measurements in both the Fresnel and far field regions. It is still unknown whether the currents determined by this method are actually the currents which exist on the array. If radiation is the only concern, it is probably unimportant whether the solution obtained is actually the source distribution which exists on the array. In this case the solution provides a good fit to the radiated fields.

Finally, it must be kept in mind that the case studied here was simple in the sense that the currents actually act as point sources for the H-plane cut considered. For arrays with more complicated elements requiring different near field pattern cuts the element current distributions become important. In this case one could apply other electromagnetic techniques to represent a more complex array element.

This technique of current determination shows sufficient promise to warrant an investigation into extending it to more complicated arrays and to continuous aperture antennas. This may require a change from discrete basis vectors to continuous basis functions to aid in enforcing boundary conditions. Also, the extention of this method will require more extensive measurement techniques. Finally, the technique described in this report shows promise as an inexpensive method to find the far field pattern of an antenna array through near field measurements. Presently, the other methods commonly used to obtain far field patterns of antennas are a far field measurement and a compact range measurement. The far field measurement has the disadvantage that a large area is needed to accomplish a measurement. The compact range has the disadvantage that it is expensive. Currently, a simple compact range costs approximately a half a million dollars.

With further development, the synthesis technique described in this report could compete with either a far field range or a compact range in the measurement of two-dimensional arrays. Also, this technique can probably be extended to antennas with continuous distributions. However, more experimental work with different antennas and more research into the theoretical aspects of the method are needed. The near field measurement device and antenna used in this study occupied 6 cubic feet and costs approximately $1500.

SCATTERING STUDIES

The electromagnetic scattering properties of complex objects at high frequencies, i.e., structures which are large in terms of the wavelength, has become a greatly discussed topic in the last few years. This interest results from the fact that analytic electromagnetic solutions for such structures have tended to be inefficient, of questionable accuracy, and give little insight into corrective measures. These shortcomings have resulted mainly from the limitations associated with the electromagnetic solutions which have been available until recently.

Most far field scattering solutions have been based on a Physical Optics (PO) approach. Using PO, one approximates the surface current by simply using the line-of-sight field incident on the scatterer. The surface current is, then, integrated around the objects; i.e., as done in a traditional antenna radiation problem, in order to obtain the scattered field. This approach is inefficient because one must integrate the currents over the surface area of a complex structure which is not a trivial task. In addition, the PO solution is of questionable accuracy. It provides a valid result for the reflected field from the various specular reflection (or flash) points on the structure; however, it results in a diffracted field which is not correct. As a result, many analysts have resorted to the Physical Theory of Diffraction (PTD) which incorporates PO with an edge diffraction correction term which is based on a line integration around the various edge contours. Using this approach, the accuracy is enhanced but it is even more inefficient. Finally, since PO as well as PTD are based on an integral representation of the scattered field, the scattering analyst gains very little insight into the mechanisms causing the total scattered field. With these thoughts in mind, the scattering community has been greatly interested in electromagnetic analyses which can bypass the limitations associated with the more traditional PO approach.

The Geometrical Theory of Diffraction (GTD) developed by Keller in the early 1950's offers one alternative method for solving electrically large scattering problems. The main advantages of GTD appears at first glance to overcome the shortcomings of PO. The GTD is a ray optical solution which implies that the total scattered field is the superposition of the individual scattering terms which emanate from isolated scattering centers such as specular reflection points, edge or corner diffractions, etc. Because the total scattered field is based on isolated scattering mechanisms, the solution is normally efficient and gives great insight into the structural properties that create the scattered field. The main limitation associated with the GTD approach has been its lack of simulation models. One should note that the GTD approach is based on the diffraction solution associated with canonical shapes. These shapes are then used to simulate the structure of interest. Since the GTD is based on edge diffraction and first order creeping wave theory, one is limited by the shortage of shapes for which diffraction solutions exist. However, the GTD has more recently been superceded by the Uniform GTD (UTD) which allows one to use a much broader class of shapes to simulate even complex structures such as aircraft, missiles, etc.

This study has attempted to provide a basic understanding of ray optical solutions and UTD, in particular. The UTD has first been developed in terms of its two dimensional behavior so that one can grasp the basic properties of this high frequency analysis without being overwhelmed by geometry. Fortunately, this background carries over directly to the three dimensional (3D) problems which have been considered next. As the 3D analysis develops, new mechanisms are needed to complete the electromagnetic solution; nevertheless, these new terms are normally an outgrowth of previous solutions. In this way, one's understanding of this topic can grow in a very logical and organized way. A report written under this study attempts to give the interested reader such a basic understanding. It is not complete by any means but should provide a basic start which allows the reader to expand upon in the future. Specific examples have been studied, in addition, such as, the scattering from plate models, composite cone fustrum models, and the near zone effects of a basic aircraft model measured at the Pacific Missile Test Center.

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